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THE EFFECTS OF EQUAL-PRESSURE FIXED SLOTS ON THE CHARACTERISTICS OF A CLARK Y AIRFOIL

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SUMMARY

A type of fixed open slot so arranged that no flow would pass through it at a lift coefficient corresponding to high-speed flight was investigated in the N.A.C.A. 7 by 10 foot wind tunnel to determine the possibilities of such a high-lift device for increasing the speed-range ratio of a wing. The condition of no through flow was achieved by locating the slot openings at points of equal static pressure at the design lift coefficient as determined from the pressure distribution about the plain wing. Two models of Clark Y wings with such equal-pressure slots were tested and the smoke-flow patterns about them observed.

The results of this investigation show that the condition of no air flow through the slot at the desired lift coefficient is attainable. The surface discontinuities produced by the slot openings have, however, such a large effect on the drag that such slots show little promise. An appreciable increase is produced in the maximum lift and the speed-range ratio can be as high as for the plain wing.

INTRODUCTION

One of the devices applied to a wing to increase its speed-range ratio that is often favorably regarded because of its mechanical simplicity is the fixed open slot. In some of its forms the fixed open slot has an adverse effect on the speed-range ratio as in the case of the leading-edge slots of reference 1. A slot near the trailing edge (reference 2) affords some increases in maximum lift and speed-range ratio. A very effective type of fixed open slot is that of the fixed auxiliary airfoil (reference 3). The air flow about the auxiliary airfoil and through the slot between it and the main wing is relatively smooth at low angles of attack, thus producing but little drag increase in return for the decided improvement in maximum lift.

In the investigation reported herein, a form of fixed open slot was tried whose lower and upper surface openings were located at points of equal static pressure as determined from the pressure distribution about the plain wing at a lift coefficient corresponding to high-speed flight. No air should flow through such a slot at the equal-pressure condition; it was therefore expected that the high-speed drag would be increased but little because the additional skin friction and disturbance of the flow about the wing produced by air passing through the slot are eliminated. The speed-range ratio would then be improved should a substantial gain in maximum lift be experienced. In order to investigate the possibilities of such a slot two models of Clark Y wings with equal-pressure fixed slots covering the range of probable shapes were accordingly tested.

APPARATUS AND TESTS

Apparatus.- The tests were made in the N.A.C.A. 7 by 10 foot open-jet wind tunnel. In this tunnel the model is mounted on the balance spindle in such a manner that the forces and moments at the quarter-chord point of the mid-section of the model are measured directly in coefficient form. A complete description of the tunnel and balance may be found in reference 4.

Models.- Two Clark Y wing models of 10-inch chord by 60-inch span were tested, both as plain wings and as wings with equal-pressure slots 1 and 2. (See figs. 1, 2, and 3.) The models were constructed of laminated mahogany to a precision of ±0.005 inch. The leading-edge portion of slot 1 was held in place by means of small metal brackets 1/32 inch thick. The two pieces of the model with slot 2 were held together with streamline boxwood spacers. The upper exit of this slot was bounded by 1/32-inch sheet metal, which also formed the upper surface of the wing in this vicinity. The openings of the slots were located at points that were at equal static pressure for a lift coefficient of 0.2 as determined from the pressure distribution about the plain wing. (See fig. 1.) The pressure distribution for 20 atmospheres pressure taken from the original data for reference 5 was used.

The sizes of the openings were the same as those found to be best in a previous investigation and the shape of the lower-surface opening agreed as nearly as possible with the best shape. (See reference 1.) The upper-surface opening was so arranged that the air would be directed as nearly tangential to the upper surface of the wing as possible.

Slot 1 (figs. 1 and 2) was located near the leading edge of the wing where the pressure distribution for the plain wing showed a large difference in pressure between the upper-surface and lower-surface openings at high lift coefficients. At lift coefficients about the same value as that at the high-speed condition, the locations of the openings corresponded to rapidly changing sections of the pressure-distribution curve.

After tests had shown that this slot caused considerable increase in the drag at high speed, tests were made on a model with slot 2 having the openings located farther back from the leading edge on the surfaces of the plain airfoil (see figs. 1 and 3), and it was thought that the increase in drag would be less than for slot 1. This slot had also equal pressures at the slot openings at $C_L = 0.2$ but a much smaller pressure difference at the high lift coefficients than slot 1 as shown by the pressure-distribution curve for the plain wing. (See fig. 1.)

Tests.- The force tests were made at a dynamic pressure of 16.37 pounds per square foot which corresponds to a speed of 80 miles per hour at sea level under standard atmospheric conditions, and to a Reynolds Number of 609,000. The following force tests were made on each model: With the slot open tests were run at angles of attack from -5° to 30°. The lift, drag, and pitching-moment coefficients were measured in these tests. Test points were taken at a sufficient number of angles to get well-defined curves; and at 1° intervals from -5° to 0° angle of attack three readings were taken at each angle to insure greater accuracy in obtaining this portion of the polar. The same tests were then repeated with the slot sealed at top and bottom to the original wing contour. Tests were also made on each model from -5° to 0° angle of attack in which only the lift and drag coefficients were measured with the slot sealed at either the top or bottom to determine, if possible, the individual contributing factors of the drag increase.

In addition to the foregoing force tests, smoke-flow tests were made in which titanium tetrachloride was introduced ahead of the slot and the flow was observed at several angles of attack near the angle of attack corresponding to a lift coefficient of 0.2. These tests were made at a Reynolds Number of about 91,500 because at higher speeds the smoke flow could not be satisfactorily observed.

RESULTS AND DISCUSSION

When titanium tetrachloride was introduced on each model ahead of the slot openings, the smoke patterns showed clearly that the condition of no flow through the slot at a designated lift could be realized. At the lift coefficient intended for equal static pressures at the slot openings ($C_L = 0.2$), a pulsating flow was observed in slot 1 surging in and spilling out at each opening and developing additional turbulence. There was no definite or steady flow of air through the slot. The only noticeable effect of slot 2 was the development of a slight additional turbulence at the entrance and exit openings. These smoke-flow observations indicate that the surface discontinuities caused by slot openings are sources of turbulence and hence of drag increases. Furthermore, such discontinuities in the high-slope regions of the pressure distribution, as for slot 1 (see fig. 1), are sources of the greater disturbance in that they allow air to move in and out of the slot.

The aerodynamic characteristics of the two Clark Y wing models with slots 1 and 2 compared with those of the plain wing are presented in figures 2 and 3, respectively. In each instance the plain wing used for comparison is the slotted model with the slot sealed. These figures show that the maximum lift coefficient is increased approximately the same amount by each slot, 22 percent by slot 1 and 19 percent by slot 2. The minimum drag, however, is increased 42 percent by slot 1 and 20 percent by slot 2. The lift-curve slope is reduced considerably in the low-lift range by both slots. At higher values of the lift coefficient the slope recovers, however, and for the wing with slot 2, it exceeds that of the plain wing. The angle of attack for maximum lift is consequently but little increased by slot 2 but by slot 1 it is raised from 17° to 26°. For both slots the diving moment tends to be reduced.

In figure 4 the term "speed-range ratio" is employed in its more general application to mean speed-range ratio corresponding to any lift coefficient. The speed-range ratio corresponding to any lift coefficient is defined as the ratio of the maximum lift to the drag at the given lift. It consequently indicates the suitability of a wing for high speed at a given lift coefficient. The curves of this ratio against C_L are shown in figure 4 for the wings with the two equal-pressure fixed slots, and for the plain Clark Y wings corresponding to each slotted wing. As in figures 2 and 3, the plain wing used for comparison with each slotted wing is that slotted wing with its slots sealed. The discrepancies indicated between the results of the different plain Clark Y wings are due mainly to model differences. From figure 4, slot 1 appears to be poor. The excessive effect on the drag produced by the slot openings is obviously to blame. Slot 2 appears to be about as good with respect to speed-range ratio as the plain wing.

In figures 5 and 6 the drag increases produced by equal-pressure slots 1 and 2, respectively, are analyzed. Polar curves are presented for various conditions of the slots: sealed (representing the plain Clark Y), open at the lower surface, open at the upper surface, and open. The drag increases produced by the slot openings are therefore shown individually and also in summation for each model, along with the drag increase due to the open slot. It may be noticed (more clearly for slot 1 than for slot 2) that the minimum drag increase produced by the open slot occurs at a lift coefficient of about 0.2, the design condition for no flow through the slot. It may be concluded that, for slots of this shape, air flow through the slot acts to increase the drag. The disadvantage of the equal-pressure slot is the large drag increases inherent in airfoil surface discontinuities such as slot openings. The drag increase due to such a discontinuity appears to be affected by its position on the profile similarly to that of a protuberance (reference 6), being less when the discontinuity is on the lower surface and when it is farther back from the leading edge. The fact that the drag for slot 2 open is lower in the low-lift range than the drag summation of the plain airfoil plus the slot openings must be left unexplained at present.

It is interesting to note that, although slot 2 has much less pressure difference operating when near maximum lift (based on the pressure distribution for the plain wing) than slot 1, its effect on maximum lift is almost as great. Inspection of the pressures at the positions of the slot openings with relation to the maximum lift for these slots and for the low-drag fixed slot of reference 1 and the trailing-edge slot of reference 2 indicates that the increase in maximum lift obtained with a fixed open slot may depend more upon the value of positive pressure at the slot entrance than on the pressure difference at maximum lift (as determined from the pressure distribution of the plain wing).

CONCLUSIONS

1. The equal-pressure slot does not show much promise because of the excessive drag increase inherent in the surface discontinuities. The maximum lift coefficient is increased, as is also the angle of attack for maximum lift, and the speed-range ratio can reach the magnitude of that of the plain wing.

2. A condition of no air flow through an open fixed slot at a lift coefficient corresponding to high speed is attainable with the equal-pressure fixed slot.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 3, 1934.

REFERENCES

1. Weick, Fred E., and Wenzinger, Carl J.: The Characteristics of a Clark Y Wing Model Equipped with Several Forms of Low-Drag Fixed Slots. T.R. No. 407, N.A.C.A., 1932.

2. Weick, Fred E., and Shortal, Joseph A.: The Effect of Multiple Fixed Slots and a Trailing-Edge Flap on the Lift and Drag of a Clark Y Airfoil. T.R. No. 427, N.A.C.A., 1932.

3. Weick, Fred E., and Sanders, Robert: Wind-Tunnel Tests on Combinations of a Wing with Fixed Auxiliary Airfoils Having Various Chords and Profiles. T.R. No. 472, N.A.C.A., 1933.

4. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

5. Jacobs, Eastman N., Stack, John, and Pinkerton, Robert M.: Airfoil Pressure Distribution Investigation in the Variable Density Wind Tunnel. T.R. No. 353, N.A.C.A., 1930.

6. Jacobs, Eastman N.: Airfoil Section Characteristics as Affected by Protuberances. T.R. No. 446, N.A.C.A., 1932.

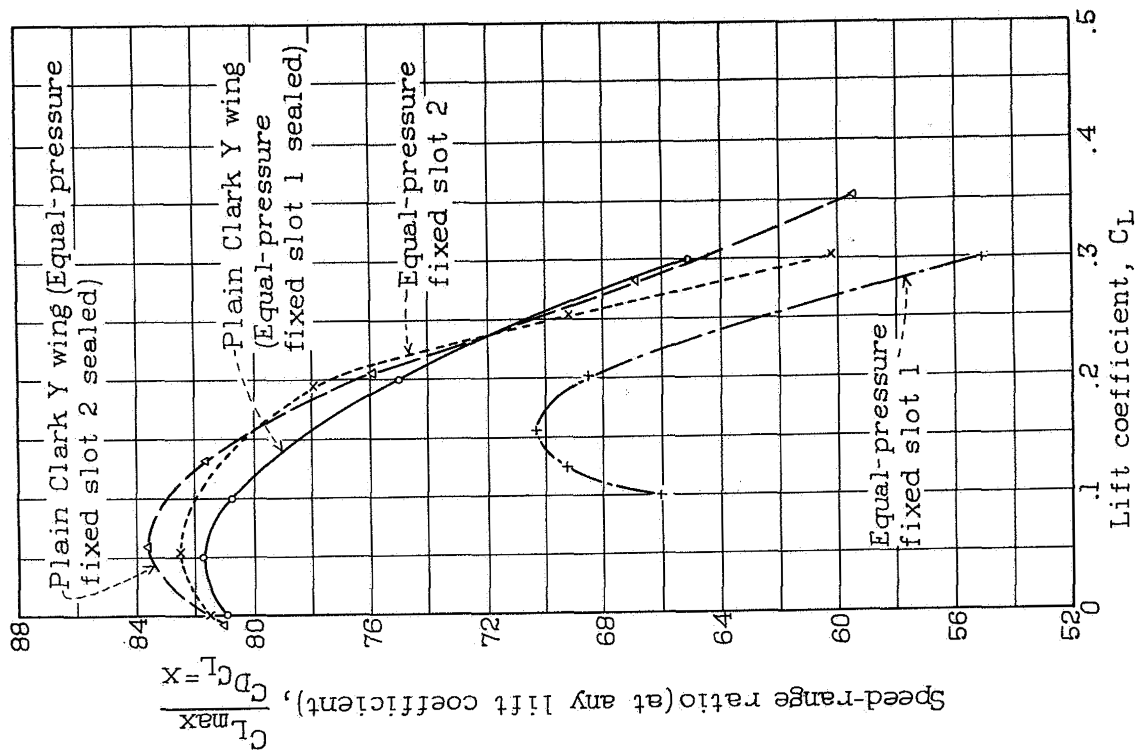

Figure 4.-Comparison of speed-range ratios. R.N=609,000

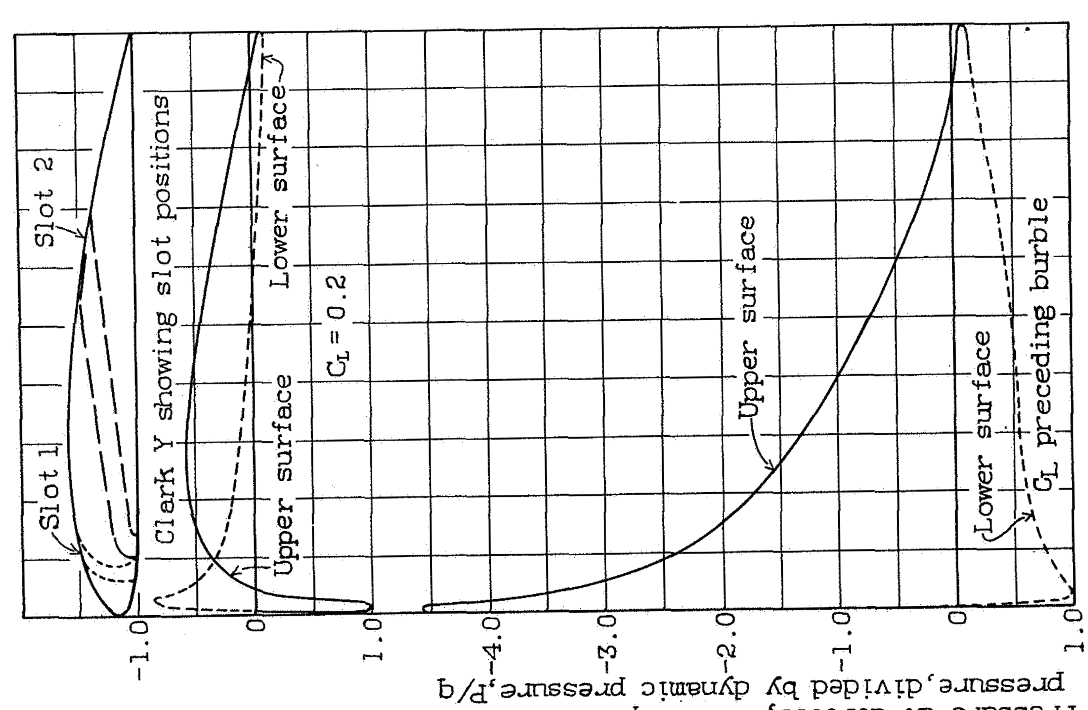

Figure 1.-Pressure distribution for Clark Y plain airfoil at two values of the lift.

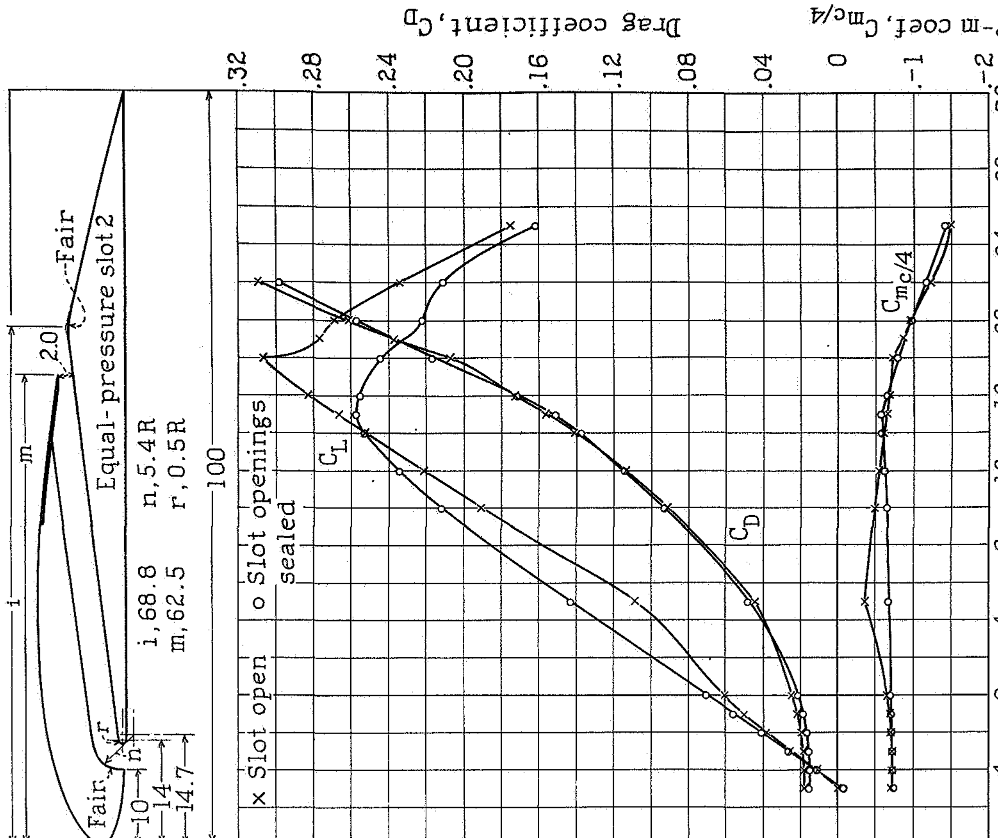

Figure 3.- Aerodynamic characteristics of Clark Y wing with equal-pressure slot 2.

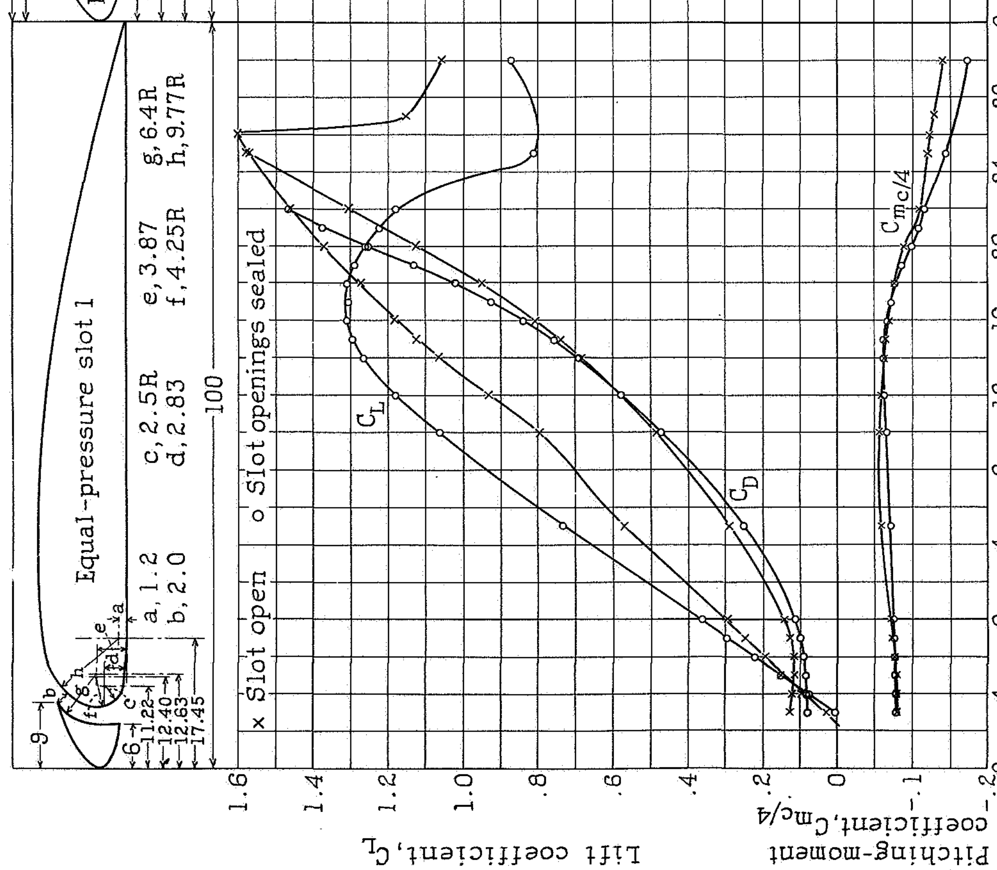

Figure 2.- Aerodynamic characteristics of Clark Y wing with equal-pres.,slot 1.

V = 80 m.p.h.; R.N. = 609,000; 7 × 10 ft. wind tunnel; 10 × 60" airfoil; Results uncorrected for tunnel-wall effects.

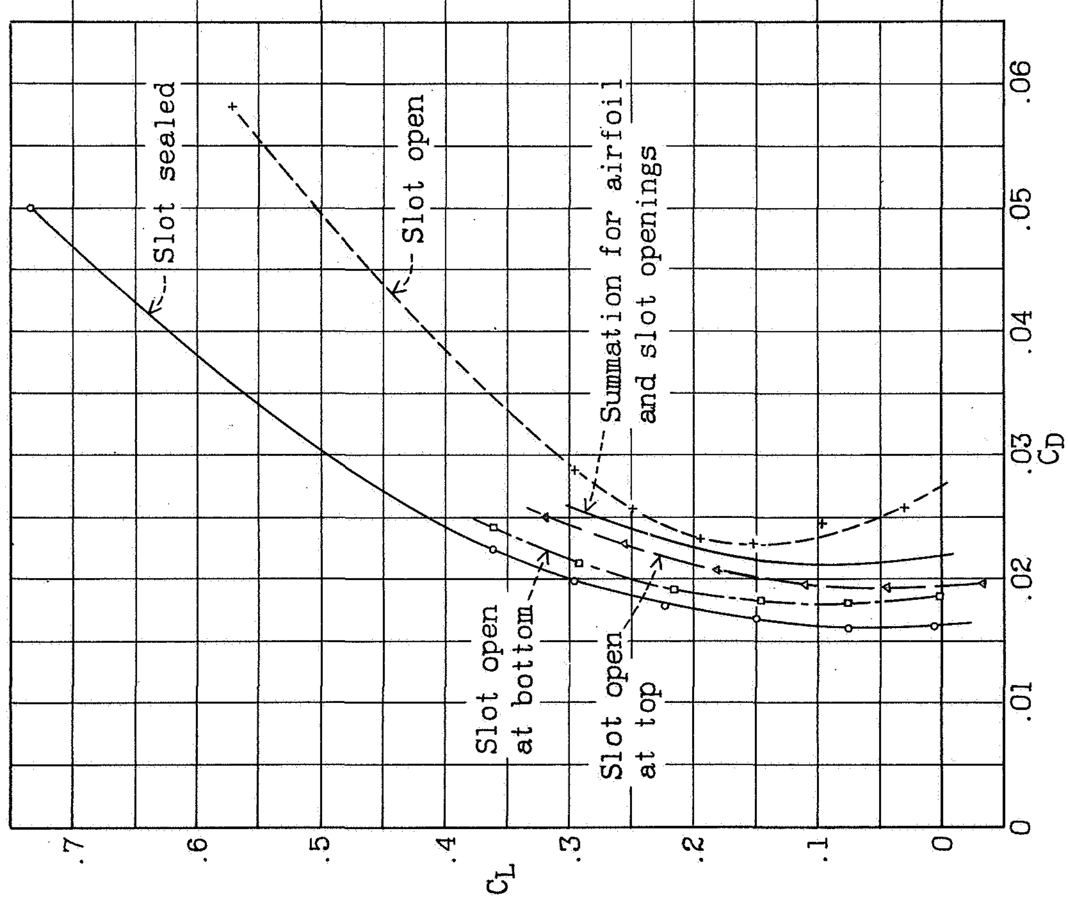

Figure 5.- Effect of slot condition on drag at low values of C_L, R.N.=609,000; Slot 1.

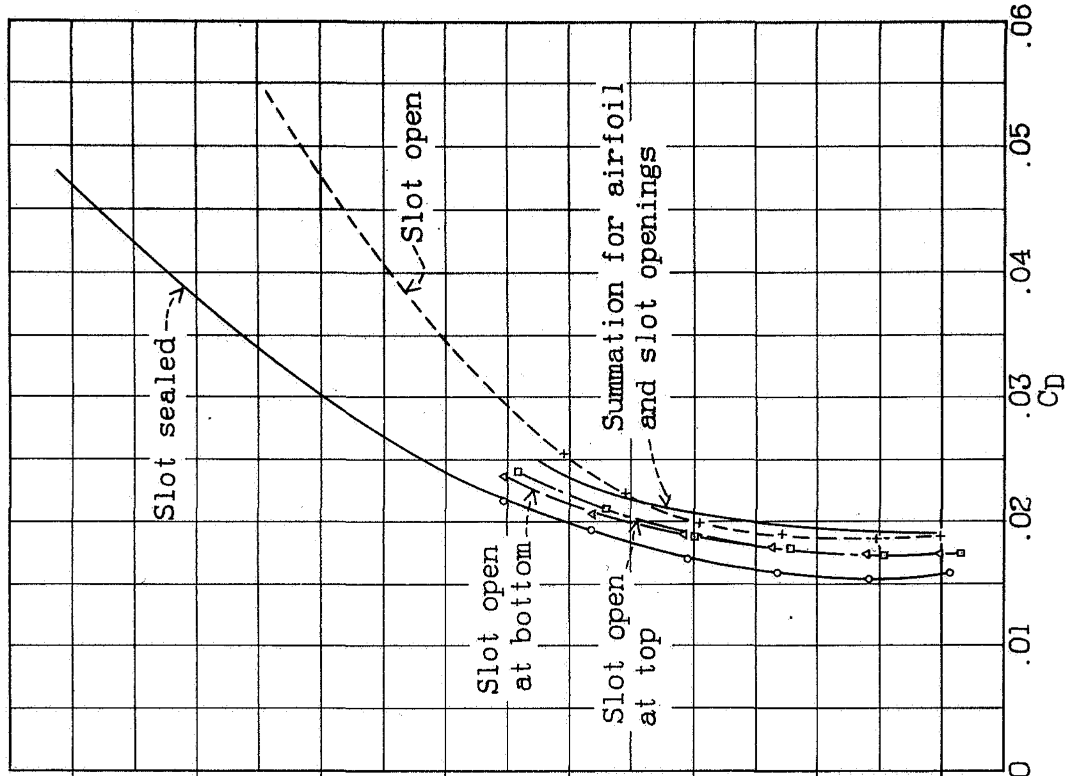

Figure 6.- Effect of slot condition on drag at low values of C_L, R.N.=609,000; Slot 2